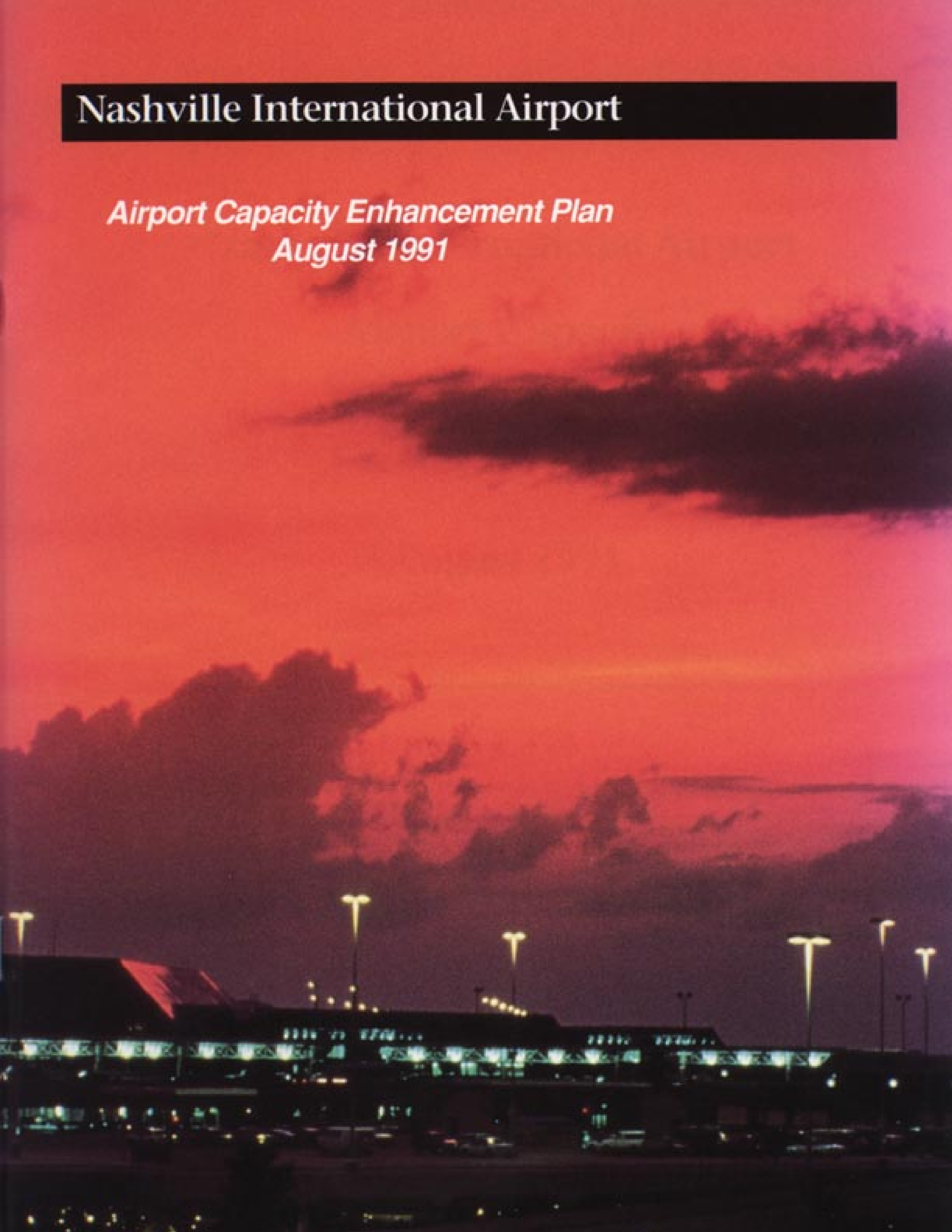
Nashville International Airport

Airport Capacity Enhancement Plan
August 1991



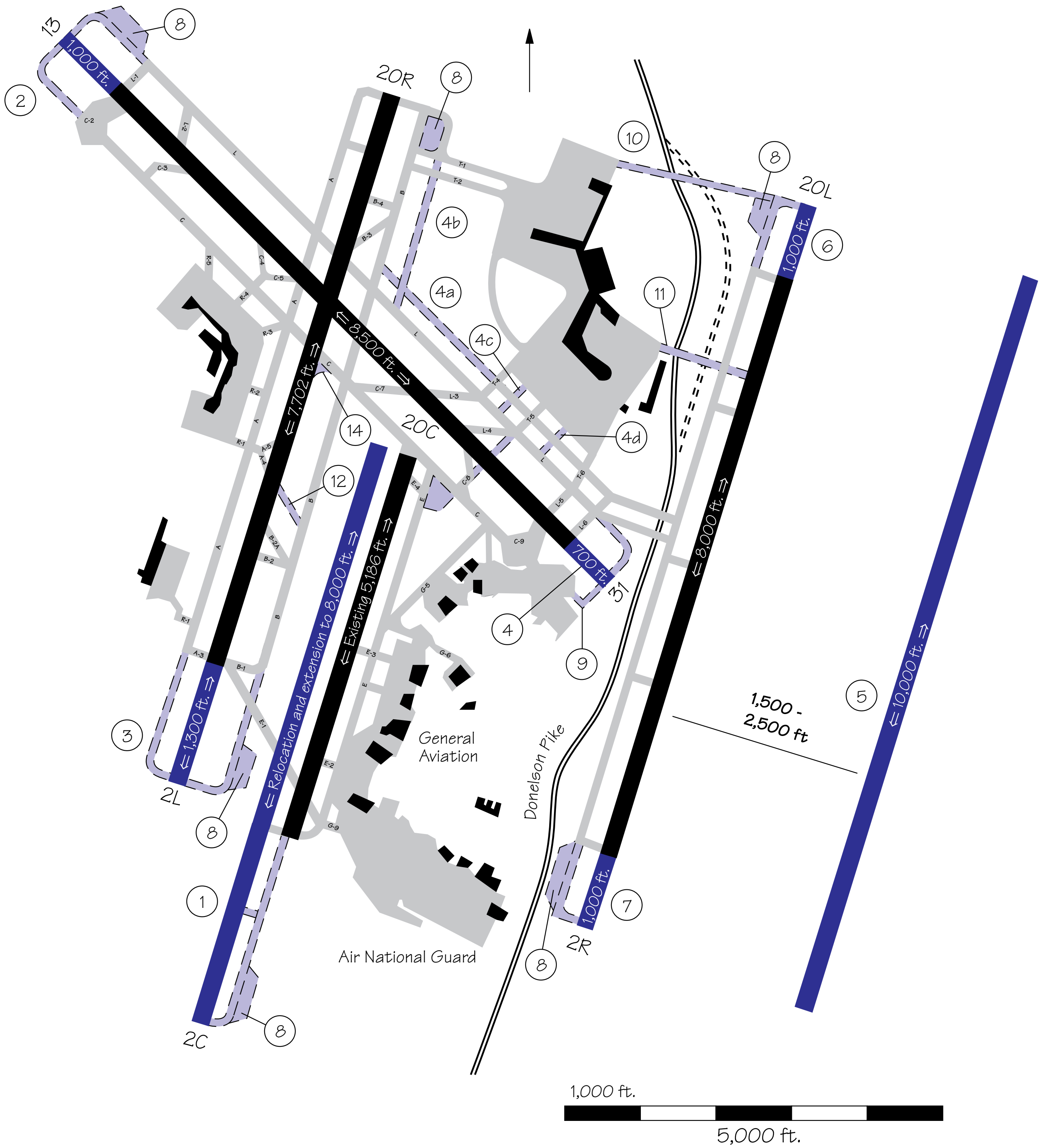
Nashville International Airport

Airport Capacity Enhancement Plan

August 1991

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, the Metropolitan Nashville Airport Authority, and the Airlines and general aviation serving Nashville.

Figure 1 Nashville International Airport



Nashville International Airport

Figure 2 Airport Delay Curve — Flow Rate Versus Average Delay

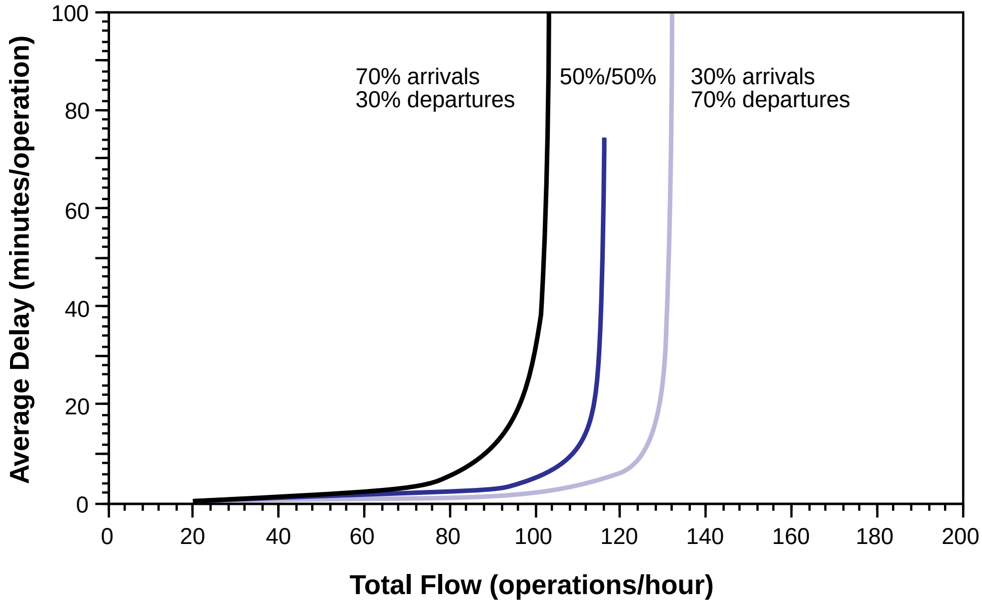
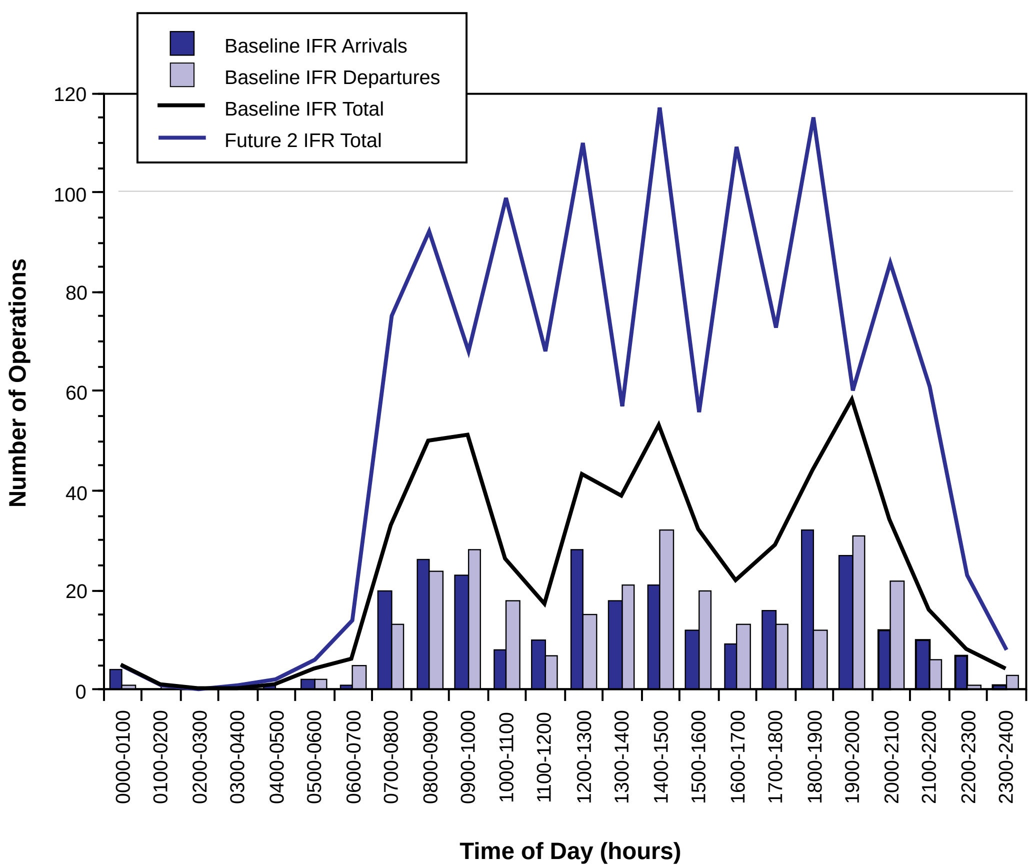


Figure 3 Profile of Daily Demand — Hourly Distribution



Summary

The Federal Aviation Administration (FAA), airport operators, and aviation industry groups have initiated Airport Capacity Design Study Teams at various major air carrier airports throughout the United States to identify and evaluate alternative means to enhance existing airport and airspace capacity to handle future demand. A Capacity Team for Nashville International Airport (BNA) was formed in 1989.

Unprecedented growth at BNA has made it one of the fastest growing airports in the country. Activity at the airport has increased from 1,141,000 passenger enplanements in 1983 to 3,447,000 in 1988, a 200% increase. In 1988, the airport handled 263,000 aircraft operations (take-offs and landings). These traffic volumes placed the airport 37th in operations and 38th in passenger enplanements among U.S. airports.

The primary objective of the Capacity Team at BNA was to identify and assess various actions which, if implemented, would increase BNA's capacity, improve operational efficiency, and reduce aircraft delays. The purpose of the process was to determine the technical merits of each alternative action and its impact on capacity. Additional studies will be needed to assess environmental, socioeconomic, or political issues associated with these actions.

Each alternative identified by the Capacity Team was tested using computer models developed by the FAA to quantify the benefits provided. Different levels of activity were chosen to represent growth in aircraft operations in order to compare the merits of each action. These annual activity levels are referred to throughout this report as: *Baseline* – 266,000 operations; *Future 1* – 417,500 operations; and *Future 2* – 534,000 operations.

If no improvements are made at BNA (the *Do Nothing* scenario), the annual delay cost will increase from $4.1 million at the Baseline (1989) level of operations to $77.4 million by Future 2.

Figure 2 (left) illustrates the capacity and delay curves for the current airfield configuration at BNA under instrument flight rules (IFR) conditions. It shows that aircraft delays will begin to escalate rapidly as hourly demand approaches 100 operations per hour. Figure 3 (left) shows that, while hourly demand doesn't exceed 100 operations at Baseline demand levels, 100 operations per hour is frequently approached or exceeded at the demand levels forecast for Future 2.

The major recommendations resulting from the BNA study include:

Improvement	Future 2 Annual Delay Savings: Hours	Future 2 Annual Delay Savings: Millions of 1989 Dollars
• Improve terminal and en route airspace.	23,193	$23.2
• Relocate Runway 2C and extend to 8,000 feet.	7,585	$7.6
• Construct connecting taxiway from Concourse D to Runway 2R/20L	7,392	$7.5
• Encourage general aviation (GA) use of reliever airports (develop Tune Airport).	3,226	$3.3
• Improve terminal taxiways and ramp.	1,034	$1.0

Figure 4 Capacity Enhancement Alternatives and Annual Delay Savings

Options	Action	Time Frame
Airfield Improvements		
1. Relocate Runway 2C and extend to 8,000 ft.	Recommended	Baseline
2. Extend Runway 13 to the northwest.	Recommended	Baseline
3. Extend Runway 2L 1,300 ft. or more to the south.	Recommended	Baseline
4. Improve terminal taxiways and ramp.	—	—
4a. Extend Taxiway I.	Recommended	Baseline
4b. Extend Taxiway B Hold.	Recommended	Baseline
4c. Construct dual lane at Taxiway T-4.	Recommended	Baseline
4d. Construct dual lane at Taxiway T-6.	Recommended	Baseline
5. Construct new Runway 2E/20E 1,500 to 2,500 ft. east of existing Runway 2R/20L.	Study*	—
5a. Less than 2,500 ft. east of 2R/20L.	—	—
5b. 2500 ft. east of 2R/20L (dependent).**	—	—
6. Extend existing Runway 20L 1,000 ft. north.	Recommended	Future 1
7. Extend existing Runway 2R 1,000 ft. south.	Recommended	Future 1
8. Construct holding (departure sequencing) pads on all runway ends (bypass capability).	Recommended	Baseline
9. Construct taxiway from GA area to Runway 31 departure end.	Recommended	Baseline
10. Construct crossover taxiway from ramp to Runway 20L.	Study*	—
11. Construct connecting taxiway from Concourse D to Runway 2R/20L.	Recommended	Baseline
12. Construct new exit for commuters east off Runway 20R at 5,000 ft.	Recommended	Baseline
13. Expand existing terminal.	Recommended	Future 1
14. Round off fillet at Taxiway C and Runway 2L.	Recommended	Baseline
15. Upgrade ILS on all existing and future runways.	Recommended	Baseline
16. Install wake vortex advisory system.	Recommended	Baseline
Operational Improvements		
17. Encourage GA use of reliever airports.	Recommended	Baseline
18. Distribute traffic uniformly within the hour.	Not Recommended	—
19. Conduct IFR dependent converging approaches. to Runways 13 and 20L.	Recommended	Baseline
20. Conduct an airspace capacity design project and re-structure terminal and en route airspace.	Recommended	Baseline
20a. Evaluate airspace restrictions.	Study*	—
20b. Revise low-altitude airway structure.	Recommended	Baseline
21. Establish a terminal control area (TCA).	Recommended	Baseline

* The term "Study" suggests either that a specific study be conducted on the particular subject or that it become part of a larger planning effort, such as a Master Plan update or a FAR Part 150 Airport Noise Compatibility Study. These individual proposals appear to have merit but may require further investigation at a level of detail that is beyond the scope of this effort.

** Benefits were calculated for three independent arrival streams assuming future technology allows them. Benefits for dependent arrival streams will be less.

Estimated Construction Cost (millions of 1990 dollars)	Estimated Annual Delay Savings (hours/millions of 1989 dollars) Baseline	Future 1	Future 2	
$33.0	***	2,969/$2.9	7,585/$7.6	(1)
$7.0-11.0		†		(2)
$17.0-57.0		†		(3)
—	***	413/$0.4‡	1,034/$1.0‡	(4)
$12.5	***	—	—	(4a)
$12.5	***	—	—	(4b)
$1.4	***	—	—	(4c)
$1.4	***	—	—	(4d)
$150.0	***	—	—	(5)
—	***	1,580/$1.6	3,239/$3.3	(5a)
—		4,371/$4.6	7,413/$7.8	(5b)
$7.9		†		(6)
$27.9		†		(7)
$16.0		†		(8)
—		†		(9)
$41.5		†		(10)
$15.0	***	4,017/$4.0	7,392/$7.5	(11)
$0.6		†		(12)
—		†		(13)
$0.4		†		(14)
$1.0 each		†		(15)
—		†		(16)
—	***	2,587/$2.6	3,226/$3.3	(17)
—	***	10,686/$10.7	19,189/$19.6	(18)
—		†		(19)
—		†		(20)
—	***	15,333/$15.1	23,193/$23.2	(20a)
—		†		(20b)
—		†		(21)

† These improvements were not simulated. Therefore, no dollar figures are available. There is a description of each of these items in Section 2 — Capacity Enhancement Alternatives.
‡ These figures represent the combined delay savings benefits for taxiway and ramp improvements 4a through 4d.
*** Delay savings benefits were not calculated for Baseline demand levels.

Table of Contents


NASHVILLE INTERNATIONAL AIRPORT

Section 1

Introduction

Background

The challenge for the air transportation industry in the nineties is to enhance existing airport and airspace capacity and to develop new facilities to handle future demand. The national air transportation system is being called on to handle unprecedented growth and ever increasing activities. As environmental, financial, and other constraints continue to restrict the development of new airport facilities in the U.S., an increased emphasis has been placed on the redevelopment and expansion of existing airport facilities.

To begin to meet this challenge, the FAA, along with airport operators and aviation industry groups throughout the country, have initiated joint industry and government Capacity Teams to study airport capacity enhancement at the major air carrier airports in the U.S. The objectives of these studies are to identify various alternatives for increasing capacity and to evaluate their potential to reduce delays.

In the past decade, Nashville International Airport (BNA) has been one of the nation's fastest growing airports. Enplanements at BNA rose from 1,141,000 in 1983 to 3,447,000 in 1988, a 200 percent increase. BNA's total aircraft operations reached 263,000 in 1988, ranking it as the 37th busiest airport in the U.S.

This report has established benchmarks for development based upon traffic levels and not upon any definitive time schedule, since growth parameters often vary within generalized time frames. As a result, the report should retain its validity until the highest traffic level is attained, regardless of the actual dates paralleling the development.

A *Baseline* benchmark was established based on the 1989 annual traffic level of 266,000 aircraft operations (takeoffs and landings). 1989 was chosen as the baseline year, since it was the latest year for which complete traffic records were available prior to the time the study commenced. Two future traffic levels, *Future 1* and *Future 2*, were established at 417,500 and 534,000 annual aircraft operations respectively, based on Capacity Team consensus of potential traffic growth at Nashville. If no improvements are made at BNA, annual delay levels and delay costs are expected to increase from an estimated 4,241 hours and $4.1 million at the Baseline activity level to 76,501 hours and $77.4 million by the Future 2 demand level.

The improvements evaluated as a part of the Capacity Team's efforts are delineated in Figure 4 and described in some detail in Section 2 - Capacity Enhancement Alternatives.

Objectives

The major goal of the Capacity Team at BNA was to identify and evaluate proposals to increase airport capacity, improve airport efficiency, and reduce aircraft delays. In achieving this objective, the Capacity Team:

- Assessed the current airport capacity and the causes of delay associated with the airfield, the immediate airspace, and the apron and gate-area operations.
- Evaluated capacity and delay benefits of alternative air traffic control (ATC) procedures, navigational improvements, airfield development, and user improvements.
- Examined the relationship between air traffic demand and delay, so that it could be used as an aid in establishing acceptable air traffic movement levels.

Scope

The Nashville Capacity Team limited its analyses to aircraft activity within the terminal area airspace and on the airfield. They considered the technical and operational feasibility of the proposed improvements, but did not address environmental, socioeconomic, or political issues regarding airport development. These issues need to be addressed in future airport system planning studies, and the data generated by the Capacity Team can be used in such studies.

Methodology

The Capacity Team proceeded along a formal sequence of events, with periodic meetings for review and coordination. The FAA Technical Center's Aviation Capacity Branch provided expertise in airport simulation modeling. Other Capacity Team members contributed suggested improvement options, data, text, and capital cost estimates.

Proposed improvements were analyzed in relation to current and future demands with the help of two computer models, the Airfield Delay Simulation Model (ADSIM) and the Runway Delay Simulation Model (RDSIM). Appendix B briefly explains the two models.

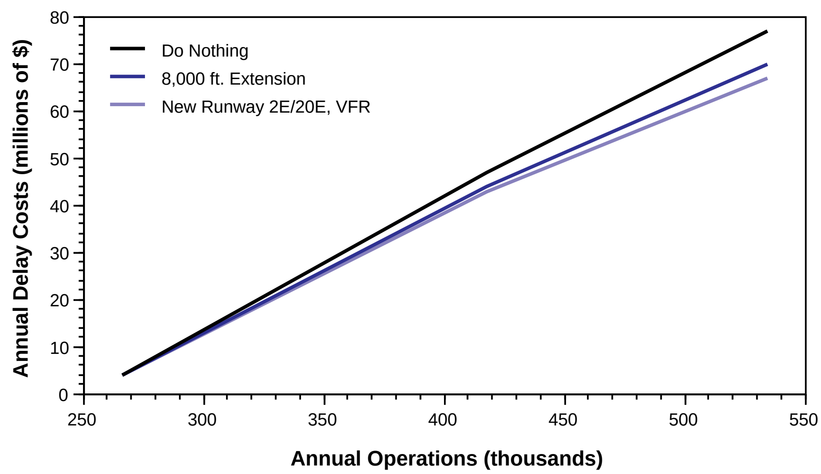
The simulation models considered air traffic control procedures, airfield improvements, and traffic demands. Alternative airfield configurations were prepared from present and proposed airport layout plans. Each configuration was evaluated to assess the benefit of projected improvements. Air traffic control procedures and system improvements determined the aircraft separations to be used for the simulations under both visual flight rules (VFR) and instrument flight rules (IFR).

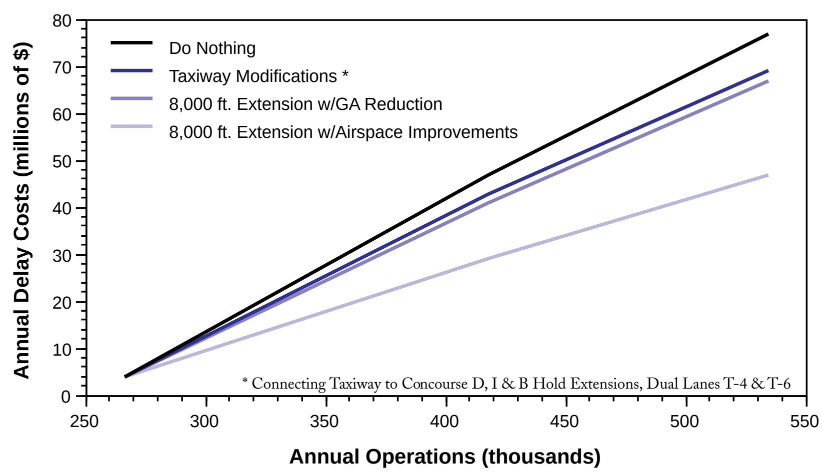
Air traffic demand levels were derived from *Official Airline Guide* data, historical data, and Capacity Team and other forecasts. Aircraft volume, mix, and peaking characteristics were considered for each of the three different demand forecast levels (Baseline, Future 1, and Future 2). From this, annual delay estimates were determined based on implementing various improvements. These estimates took into account historic variations in runway configuration, weather, and demand. The annual delay estimates for each configuration were then compared to identify delay reductions resulting from the improvements.

Following the evaluation, the Capacity Team developed a plan of "Recommended Alternatives" for consideration, which is shown in Figure 4.

Figure 5 demonstrates the impact of delays at Nashville International Airport. The charts show how delay costs will continue to grow at a substantial rate as demand increases if there are no improvements made in airfield capacity, i.e., the "Do Nothing" scenario. The charts also show that the greatest savings in airfield delay costs would be provided by relocating and extending Runway 2C, implementing airspace improvements, constructing taxiway improvements, and constructing a new parallel runway (2E/20E) capable of accommodating large air carrier transport aircraft.

Figure 5 Annual Delay Costs
Capacity Enhancement Alternatives





Section 2

Capacity Enhancement Alternatives

Figure 1 shows the current layout of the airport, plus the recommended improvements. The BNA Capacity Team selected the capacity enhancement alternatives listed in Figure 4 for evaluation.

Figure 4 presents the recommended action and suggested time frame for each improvement evaluated for the activity levels, *Baseline*, *Future 1*, and *Future 2*, which correspond to annual aircraft operations of 266,000 (base level for 1989), 417,500, and 534,000 respectively. Benefits of the improvements are not necessarily additive.

The capacity enhancement alternatives are categorized and discussed under the following headings:

- Airfield Improvements.
- Facilities and Equipment Improvements.
- Operational Improvements.

Airfield Improvements

1. Relocate Runway 2C and extend to 8,000 feet.

The Metropolitan Nashville Airport Authority is currently constructing an extension to Runway 2C to 6,000 feet to accommodate the significant increases in regional commuter operations at BNA.

Under this project, Runway 2C will be relocated 400 feet further to the west, and runway length will be increased to 8,000 feet. The existing Runway 2C will also be extended to 8,000 feet for use as a parallel taxiway. This project will provide increased flexibility for arrival and departure operations in conjunction with Runway 2L. It will also allow for a separate apron-edge taxiway for general aviation situated immediately to the east.

Estimated 1990 construction cost is $33 million.

Annual savings at the Future 1 activity level will be 2,969 hours or $2.9 million, and, at Future 2 activity levels, 7,585 hours or $7.6 million.

2. Extend Runway 13 to the northwest.

This project would address the immediate need for a runway with a length of 10,000 to 11,000 feet. It will allow for a 1,000 foot or greater extension of Runway 13 (with parallel Taxiways C and L) to accommodate transcontinental and intercontinental operations. For evaluation purposes, an extension of 1,000 feet to the northwest was analyzed by the Capacity Team.

The Airport Authority is currently extending Runway 13/31 740 feet to the southwest to provide additional departure runway length.

Estimated 1990 construction cost is $7 to $11 million.

3. Extend Runway 2L 1,300 feet or more to the south.

This project will provide transcontinental and intercontinental stage length capability as an airfield element of the existing parallel runway system. For evaluation purposes, an extension of 1,300 to 3,300 feet to the south was analyzed by the Capacity Team. Extensions beyond 1,000 feet may be required to meet established facility requirements. Because of the time required to construct this extension, it is anticipated that Runway 13/31 will provide the initial stage length capability.

Estimated 1990 construction cost is $17 to $57 million.

4. Improve terminal taxiways and ramp.

The combined annual savings for these four improvements at the Future 1 activity level will be 413 hours or $0.4 million, and, at Future 2 activity levels, 1,034 hours or $1.0 million.

4a. Extend Taxiway I.
4b. Extend Taxiway B hold.

The extension of these terminal-quadrant taxiways would provide significant operations flexibility for movement of aircraft in the terminal area during peak periods. In order to construct these taxiways, fill material would be provided through coordination with the roadway improvement project to realign Donelson Pike. The realignment of Donelson Pike would reduce existing line-of-sight problems and provide for the construction of a future connector taxiway from the terminal apron to Runway 2R (See alternative 11, Construct connecting taxiway from Concourse D to Runway 2R/20L).

Estimated 1990 construction cost for these two taxiway extensions is $25.0 million.

4c. Construct dual lane at Taxiway T-4.

Completion of a dual lane at Taxiway T-4 will reduce taxi interference and delays by allowing two-way traffic for arriving and departing aircraft using Taxiway T-4 to taxi to and from the terminal and runway.

Estimated 1990 construction cost is $1.4 million.

4d. Construct dual lane at Taxiway T-6.

Completion of a dual lane at Taxiway T-6 will reduce taxi interference and delays by allowing two-way traffic for arriving and departing aircraft using Taxiway T-6 to taxi to and from the terminal and runway.

Estimated 1990 construction cost is $1.4 million.

5. Construct new Runway 2E/20E

Construction of additional runway capabilities will provide for the needs of BNA beyond the Master Plan (20-year) demand level. The Capacity Team encourages the Airport Authority to thoroughly investigate a future Runway 2E/20E as a part of the recently initiated Master Plan update for BNA.

Estimated 1990 construction cost is $150.0 million.

5a. Less than 2,500 feet east of Runway 2R/20L.

If the new runway is constructed less than 2,500 feet to the east, it will allow for three VFR arrival streams or two IFR arrival streams and a dedicated IFR departure runway. The annual delay savings are forecast to be 1,580 hours which will save $1.6 million each year at the Future 1 level of operations and 3,239 hours or $3.3 million annually at Future 2 levels.

5b. 2,500 feet east of Runway 2R/20L (dependent).

If the new runway is constructed 2,500 feet east of the existing Runway 2R/20L, it could allow three VFR arrival streams and three IFR arrival streams, one of which will be dependent (staggered).

If the Precision Runway Monitor (PRM) currently under development allows new IFR triple approach procedures, a new runway at 2,500 feet could support three VFR arrival streams and three independent IFR arrival streams. At Future 1 activity levels, the annual delay savings are forecast to be 4,371 hours or $4.6 million, and at the Future 2 levels, 7,413 hours or $7.8 million per year.

6. Extend existing Runway 20L 1,000 feet north.

This project consists of extending Runway 20L and its associated Taxiway H 1,000 feet to the north. Previous planning efforts have recognized this element as achievable, however, significant financial resources must be devoted. When completed, this development will provide additional pavement permitting additional aircraft stage length.

Estimated 1990 construction cost is $7.9 million.

7. Extend existing Runway 2R 1,000 feet south.

This project consists of extending Runway 2R and its associated Taxiway H 1,000 feet to the south. The ultimate goal of this initiative will be to maximize existing runway alignments to provide transcontinental and international operational capability to Nashville.

Estimated 1990 construction cost is $27.9 million.

8. Construct holding (departure sequencing) pads on all runway ends (bypass capability).

As air carrier activity at the airport increases, air traffic flow control may require more aircraft to hold at the runway thresholds before takeoff because of departure fix restrictions. To reduce delays, it will be necessary to expand the staging areas at the ends of the runways to improve the ability of departing aircraft to bypass those aircraft waiting for departure clearance.

The estimated construction cost in 1990 dollars is $16 million.

9. Construct taxiway from the GA area to Runway 31 departure end.

This project will provide a more direct route for general aviation (GA) aircraft to and from the GA ramp area and Runway 31, reduce taxi interference, and shorten taxi travel times.

10. Study construction of a crossover taxiway from ramp to Runway 20L.

This project would provide a more direct route for aircraft to and from the terminal ramp and Runway 20L. It will reduce taxi distances from the north ramp to Runway 2R/20L. This alternative should be studied in the Master Planning process.

Estimated 1990 construction cost is $41.5 million.

11. Construct connecting taxiway from Concourse D to Runway 20L/2R.

This project will provide a more direct route for aircraft to and from Terminal Concourse D and Runway 20L/2R. It will reduce taxi interference in the ramp area and shorten taxi delays and taxi travel times (see alternative 4).

Estimated 1990 construction cost is $15 million.

The annual delay savings are forecast to be 4,017 hours, which will save $4.0 million each year at the Future 1 level of operations, and 7,392 hours or $7.5 million annually at Future 2 levels. These savings assume that the combined taxiway and ramp improvements outlined in alternatives 4a through 4d are in place before this connecting taxiway is added. The savings listed here are the additional savings that would result from adding the connector.

12. Construct new exit for commuters east off Runway 20R at 5,000 feet.

This project will provide a more convenient exit for arriving commuter aircraft off Runway 20R. This will reduce the runway occupancy times of arriving aircraft and shorten the taxi time to the terminal for certain aircraft.

Estimated 1990 construction cost is $0.6 million.

13. Expand existing terminal.

This project will provide an additional 20 to 25 gates to accommodate the increase in air carrier aircraft operations forecast for Future 1 and 2. Expansion of the terminal will occur at the existing concourses, A, B, C, and D, but an additional concourse may be required. The actual configuration of the expansion will be determined as a part of the process of updating the airport's Master Plan.

14. Round off fillet at Taxiway C and Runway 2L.

Widening the turn-back fillet at the intersection of Runway 2L and Taxiway C will allow larger aircraft to make the sharp turn onto Taxiway C. This will reduce the runway occupancy times of arriving aircraft and shorten the taxi time to the terminal for certain aircraft.

The estimated construction cost in 1990 dollars is $0.4 million.

Facilities and Equipment Improvements

15. Upgrade ILS on all existing and future runways.

Adding or upgrading ILS on all runway ends to Category II/III will provide complete all-weather operating capability. This development will reduce visibility minimums and thereby maintain capacity during instrument meteorological conditions (IMC). The feasibility of this initiative depends on the ability to adapt each ILS installation to local terrain and surface features effectively and economically.

The estimated cost to upgrade a Category I ILS to Category II/III is $1.0 million in 1991 dollars.

16. Install wake vortex advisory system.

Since the turbulence created by heavy aircraft at landing and take-off speeds (wake vortices) can be hazardous to trailing aircraft, the FAA has established minimum separations to eliminate the hazards of wake vortices. Installation of a wake vortex advisory system would allow for improved separation.

Operational Improvements

17. Encourage general aviation (GA) use of reliever airports.

If general aviation aircraft were encouraged to use other airports to serve the Nashville metropolitan area, airfield capacity at BNA would become available for additional commercial aircraft. Safe and reliable airside facilities and attractive service facilities would need to be provided at other reliever airports. Ground transportation connections may be necessary.

The Nashville Metropolitan Area has designated reliever airports within the *National Plan of Integrated Airport Systems* (NPIAS). The John C. Tune Airport, situated adjacent to the downtown business district, would serve as a better reliever airfield for BNA for GA instrument flight operations if a full ILS were installed. An ILS at Tune would enhance GA operations and reduce delays during instrument meteorological conditions (IMC) at Nashville International.

To determine the benefits of enhancing reliever airports, the Capacity Team evaluated the effects of reducing the number of small, slow aircraft by 50 percent. A 50 percent reduction would save 2,587 hours or $2.6 million per year at the Future 1 level of demand, and 3,226 hours or $3.3 million at the Future 2 level.

18. Distribute traffic uniformly within the hour.

A more even distribution of airline flights during peak periods would promote a more orderly flow of traffic near the terminal and on the taxiway system. Annual savings at the Future 1 activity level would be 10,686 hours or $ 10.7 million, and, at Future 2 activity levels, 19,189 hours or $ 19.6 million per year.

However, BNA is an integral part of the hub-and-spoke operation, and uniform distribution of traffic is not consistent with such an operation. Hubbing creates efficiencies that cannot be measured in a delay study of this type. This system of operations provides frequent service between city-pairs that could not support frequent direct service. Frequent flights provide an economic benefit to consumers, in particular the business flyer. In order to properly evaluate the overall impact of hubbing and the redistribution of scheduled operations, the entire system must be studied, not any one individual airport.

19. Conduct IFR dependent converging approaches to Runways 13 and 20L.

Developing the necessary air traffic control procedures to support dependent converging approaches to Runways 13 and 20L during IFR conditions will provide the capability for dual-stream operations and enable an increased number of arriving aircraft to have access to the airfield.

20. Conduct an airspace capacity design project and re-structure terminal and en route airspace.

The Capacity Team highly recommends a complete analysis of all of the en route airspace that interconnects with BNA. This analysis should include concepts of airspace restructuring that offer the potential for improving arrival and departure air route capacity in conjunction with airport improvements. New technology and operating concepts need to be reviewed in an effort to improve flow-control procedures and reduce or eliminate miles-in-trail restrictions that are beyond optimal aircraft spacing. The goal would be to insure sufficient airspace capacity to fully utilize the airport's surface capacity.

When the en route airspace capacity design project is completed, an appropriate restructuring of terminal area should be implemented to ensure the entire air traffic control system is capable of using the increased airport capacity.

20a. Evaluate airspace restrictions.

If all aircraft presently operating at BNA were allowed to operate free of noise restrictions and miles-in-trail departure fix restrictions, there would be a significant reduction in annual delays. Annual savings at the Future 1 activity level will be 15,333 hours or $15.1 million, and, at Future 2 activity levels, 23,193 hours or $23.2 million. The Metropolitan Nashville Airport Authority is committed to an aggressive noise compliance plan and a comprehensive compatible land use plan.

Currently, about 46 percent of the fleet of aircraft serving BNA meet Stage III noise requirements, with 82 percent projected for Future 1 and 90 percent for Future 2.

20b. Revise low-altitude airway structure.

The revision of the airway structure in the Nashville area will have a favorable effect on arrival and departure operations. The desired concept will limit ingress and egress points for en route traffic into and out of the terminal area, thus allowing arrival and departure airspace to be used in a more efficient manner. This restructuring will increase the overall traffic-handling capabilities of the Nashville air traffic control tower.

21. Establish a terminal control area (TCA).

Establishing a TCA in the Nashville terminal airspace would bring all aircraft operating within that airspace under positive control. Besides the obvious increase in safety, a TCA allows the controller to adjust the volume and flow of traffic and provides a more positive control of all traffic situations.

Section 3

Summary of Technical Studies

Overview

The Nashville Capacity Team evaluated the efficiency of the existing airfield and the proposed future configuration. Figure 6 illustrates airfield weather conditions, and Figure 7, runway utilization. The potential benefits of various improvements were determined by examining airfield capacity, airfield demand, and average aircraft delays.

The Capacity Team used the Runway Delay Simulation Model (RDSIM) to determine aircraft delays during peak periods. Delays were calculated for current and future conditions.

Daily operations corresponding to an average day in the peak month were used for each of the forecast periods. Daily delays were annualized to measure the potential economic benefits of the proposed improvements. The annualized delays provide a basis for comparing the benefits of the proposed changes. The benefits associated with various runway use strategies were also identified.

The fleet mix at Nashville International Airport (BNA) results in an average direct operating cost of $16.44 per minute. This figure represents the costs for operating the aircraft and includes such items as fuel, maintenance, and crew costs, but it does not consider lost passenger time, disruption to airline schedules, or any other intangible factors.

The cost of a particular improvement was measured against its annual delay savings. This comparison indicates which improvement will be the most effective.

For expected increases in demand, a combination of improvements can be implemented to allow airfield capacity to increase while aircraft delays are minimized.

Figure 6 Airfield Weather

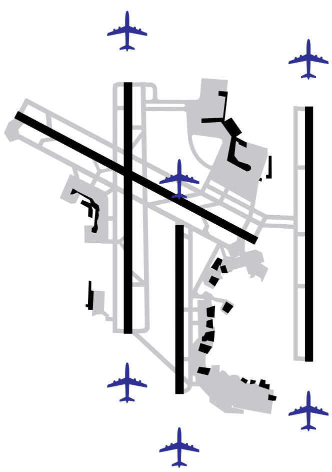
Condition	Ceiling/Visibility	Occurrence (%)
VFR	1,500 feet/3 SM or above	81
IFR 1	Between 1,499 and 200 feet/3 and .5 SM	18
IFR 2	Below 200 feet/.5 SM	1

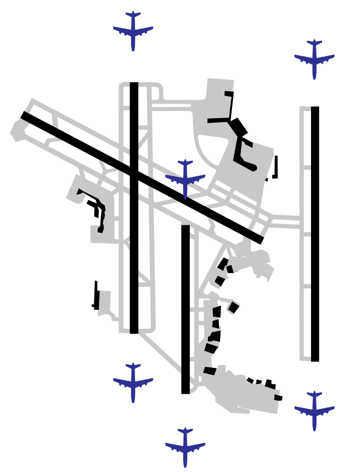
VFR - Visual Flight Rules
IFR - Instrument Flight Rules
SM - Statute Miles

Figure 7 Runway Utilization

VFR

40.5%

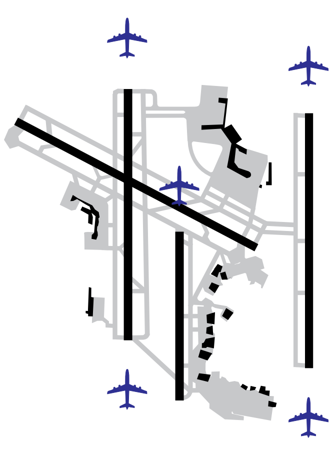


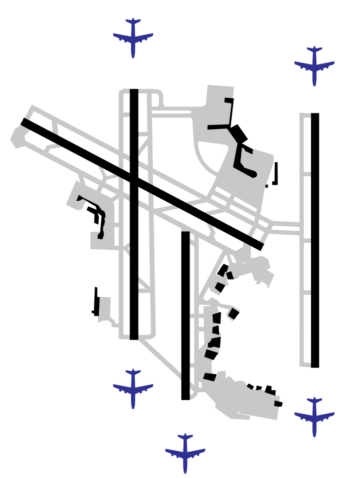


40.5%

IFR

9.5%





9.5%

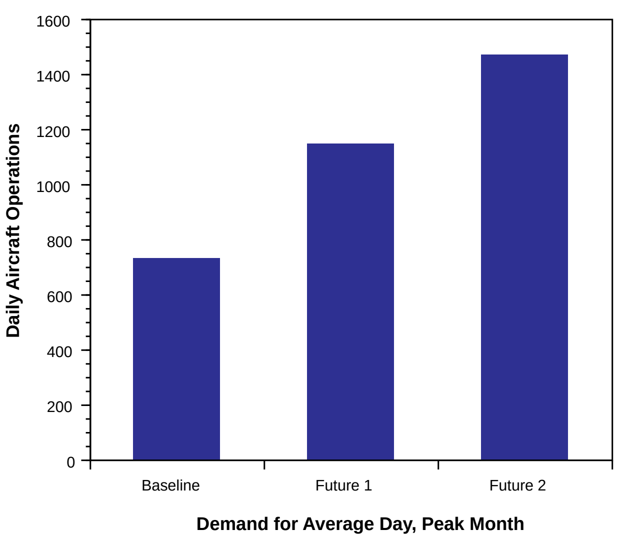
Airfield Capacity

The BNA Capacity Team defined airfield capacity to be the maximum number of aircraft operations (landings or takeoffs) that can take place in a given time. They recognized that airfield capacity is a very complex problem that cannot be represented by a constant value, but varies as conditions change. In its analysis, the Capacity Team considered the following conditions:

- Acceptable level of delay
- Airspace constraints
- Ceiling and visibility conditions
- Runway layout and use
- Aircraft mix
- Percent arrival versus departure demand

Figure 8 illustrates the average-day, peak-month arrival and departure demand levels for BNA for each of the three annual activity levels used in the study, Baseline, Future 1, and Future 2.

Figure 8 Airfield Demand Levels - Aircraft Operations and Average Day of Peak Month



	Annual Demand	Daily Total	Peak Hour
Baseline	266,000	730	65
Future 1	417,500	1,147	117
Future 2	534,000	1,468	129

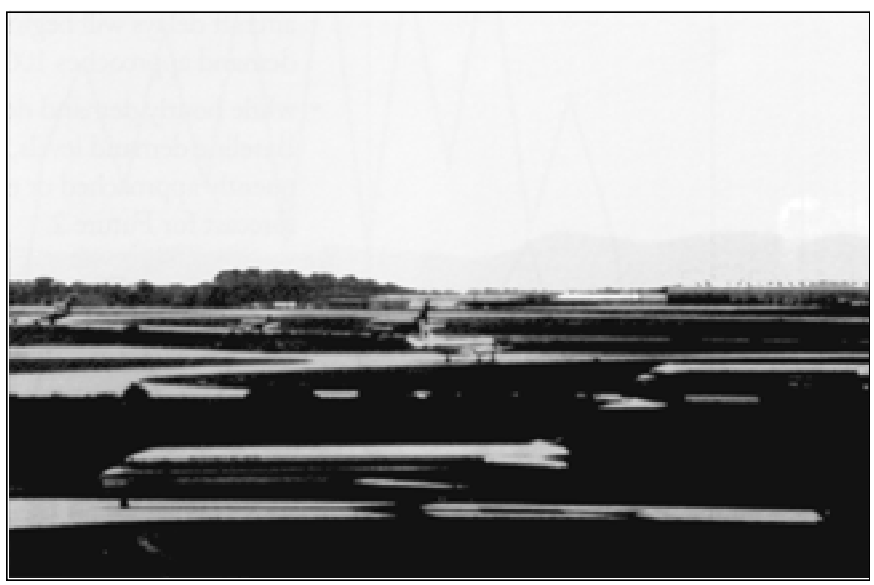


Figure 9 presents the airport delay curves for BNA. The curves were developed for various runway configurations, under instrument flight rules (IFR) conditions, with a 70/30, 50/50, and 30/70 split of arrivals and departures. These curves are based on the assumption that arrival and departure demand is randomly distributed within the hour. Other patterns of demand can alter the demand/delay relationship.

The curves in Figure 9 illustrate the relationship between flow, the number of operations per hour, and the average delay per aircraft. They show that, as the number of aircraft operations per hour increases, the average delay per operation increases exponentially.

It is also important to notice that, as flow increases, average aircraft delay increases moderately until it reaches about four minutes per aircraft. Once delay reaches this point, an increase in flow can only be realized with significantly increasing delays. Therefore, even when the airport is operating at a relatively low level of delay, a small increase in demand can cause a significant increase in delay.

Figure 10 illustrates the hourly profile of daily demand for the Baseline activity level of 266,000 aircraft operations per year. It also includes a curve that depicts the profile of daily operations for the Future 2 activity level of 534,000 aircraft operations per year.

Comparing the information in Figures 9 and 10 shows that:

- aircraft delays will begin to rapidly escalate as hourly demand approaches 100 operations per hour, and,
- while hourly demand doesn't exceed 100 operations at Baseline demand levels, 100 operations per hour is frequently approached or exceeded at the demand levels forecast for Future 2.

Figure 9 Airport Delay Curve — Flow Rate Versus Average Delay

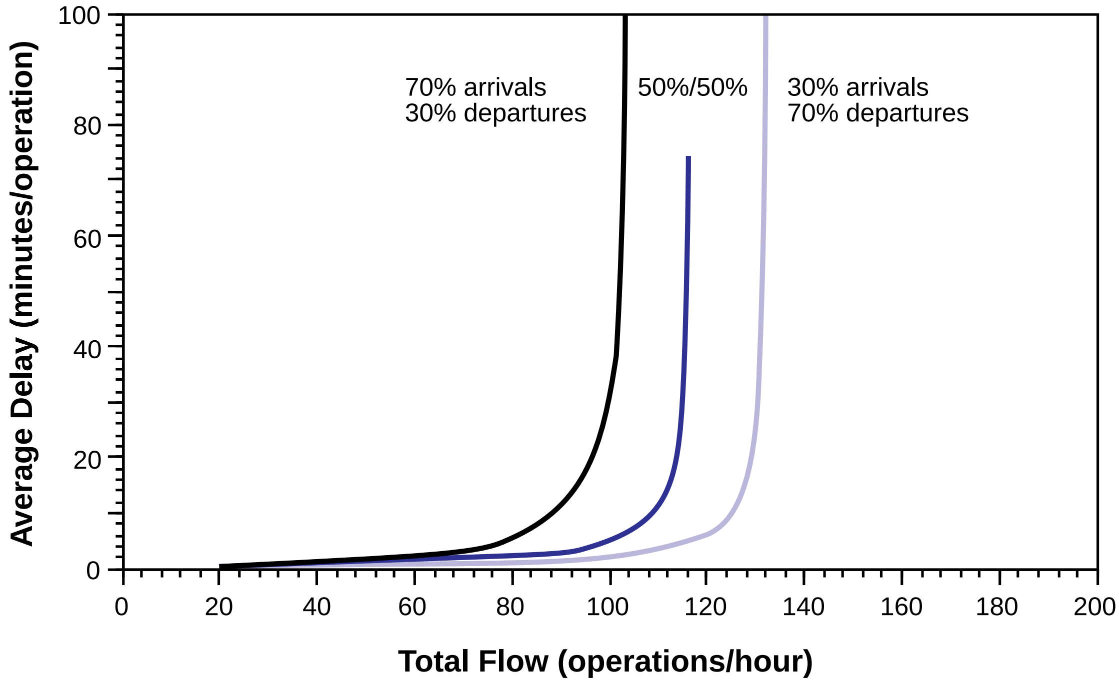
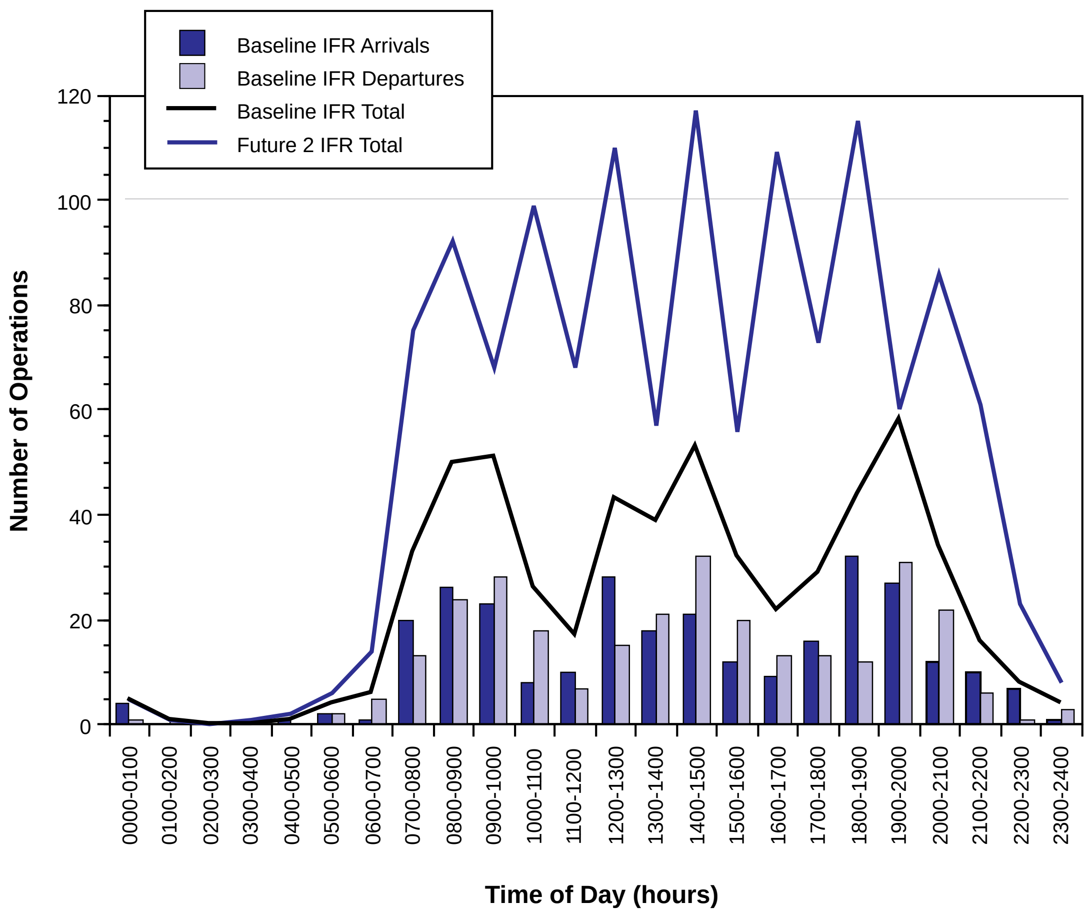


Figure 10 Profile of Daily Demand



Aircraft Delays

Aircraft delay is defined as the time above the unimpeded travel time for an aircraft to move from its origin to its destination. Aircraft delay results from interference from other aircraft in the system competing for the use of the same facilities.

The major factors influencing aircraft delays are:

- Weather
- Airfield and ATC system demand
- Airfield physical characteristics
- Air traffic control procedures
- Aircraft operational characteristics

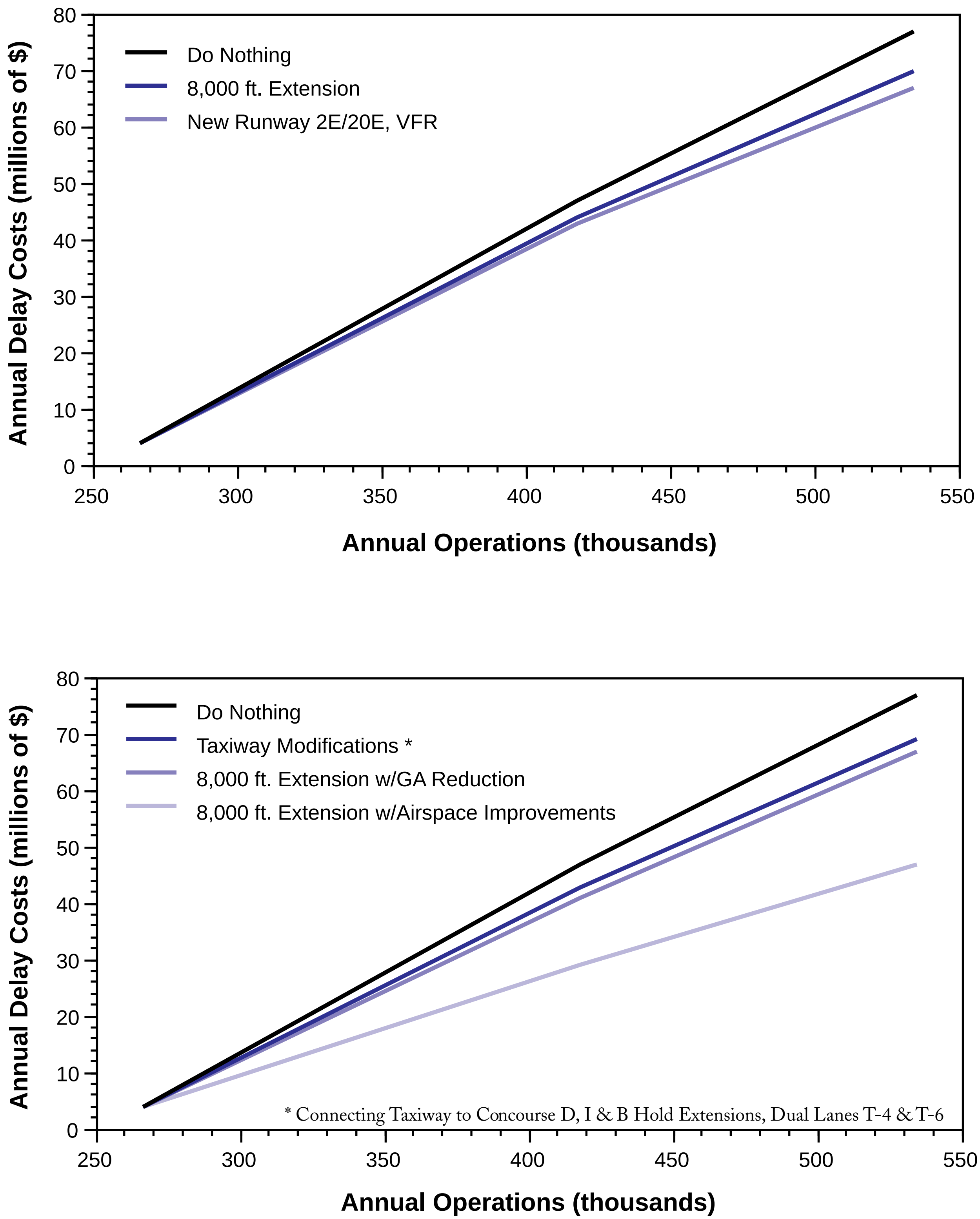
Average delay in minutes per operation was generated by the Runway Delay Simulation Model (RDSIM). A description of this model is included in Appendix B. If there are no improvements in airfield capacity, the average delay per operation of 1.0 minutes in Baseline will increase to the unacceptable level of 8.6 minutes per operation by Future 2.

Annual delay costs, expressed in millions of dollars, for various demand levels are shown in Figure 11. This figure presents comparisons between "Do Nothing" and the capacity enhancement alternatives. It also identifies the benefit that would result from implementing the individual alternatives.

Under the "Do Nothing" situation, if there are no improvements made in airfield capacity, the annual delay cost will increase as follows:

	Annual Delay Costs	
	Hours	Millions of 1990 $
Baseline (1989)	4,241	$4.1
Future 1	47,125	$47.1
Future 2	76,501	$77.4

Figure 11 Annual Delay Costs — Capacity Enhancement Alternatives



Appendix A

Capacity Team Participants

FAA Southern Region (Airports)	Pablo Auffant Edward Agnew
FAA Nashville Air Traffic Control Tower	Herschel Anderson Tom Martin James Stephenson
American Airlines	Roy Harmon Larry Benno
FAA HQ System Capacity Office	Jim Smith Anees Adil
Metropolitan Nashville Airport Authority	Ray White Tim Campbell
FAA Technical Center	John Vander Veer Bob Holladay Richard Soper
Air Transport Association of America	Bill Drew
Aircraft Owners and Pilots Association	Bob Minter
Tennessee Air National Guard	Major Mike Russell

Appendix B

Computer Models and Methodology

The BNA Capacity Team studied the effects of various improvements proposed to reduce delay and enhance capacity. The options were evaluated considering the anticipated increase in demand. The analysis was performed using several computer modeling techniques. A brief description of the models and the methodology employed follows.

Computer Models

Airfield Delay Simulation Model (ADSIM)

This is a fast-time, discrete event model that employs stochastic processes and Monte Carlo sampling techniques. It describes significant movements of aircraft on the airport and the effects of delay in the adjacent airspace. The model was validated in 1978 at Chicago O'Hare International Airport against actual flow rates and delay data. It was calibrated for this study against field data collected at BNA to insure that the model was site specific.

Inputs for the simulation model were derived from empirical field data. The model repeated each experiment 10 times using Monte Carlo sampling techniques to introduce system variability. The results were averaged to produce output statistics. Total and hourly aircraft delays, travel times, and flow rates for the airport and for the individual runways were calculated.

Runway Delay Simulation Model (RDSIM)

There are two forms of the RDSIM model. The first is a short version of the ADSIM model that simulates only the runways and runway exits. This version ignores the taxiway and gate complexes for a user-specified daily traffic demand. The second version also simulates the runway and runway exits, but it creates its own demand using randomly assigned arrival and departure times. The demand created is based upon user-specified parameters. This form of the model is suitable for capacity analysis.

For a given demand, the model calculates the hourly flow rate and average delay per aircraft during the full period of airport operations. Using the same aircraft mix, different demand levels were simulated for each run to generate demand versus delay relationships.

Methodology

Model simulations included present and future air traffic control procedures, various airfield improvements, and traffic demands for different times. To assess the benefits of proposed airfield improvements, the FAA used different airfield configurations derived from present and projected airport layouts. The projected implementation time for air traffic control procedures and system improvements determined the aircraft separations used for IFR and VFR weather simulations.

For the delay analysis, agency specialists developed traffic demands based on the *Official Airline Guide*, historical data, and various forecasts. Aircraft volume, mix and peaking characteristics were developed for three demand periods (Baseline, Future 1 and Future 2). The estimated annual delays for the proposed improvement options were calculated from the experimental results. These estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data.

The potential delay reductions for each improvement were assessed by comparing the annual delay estimates.

The RDSIM model, in its capacity mode, was used to perform the capacity analysis for BNA.

Appendix C

Glossary

ADSIM	Airfield Delay Simulation Model
AOPA	Aircraft Owners and Pilots Association
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
BNA	Nashville International Airport
FAA	Federal Aviation Administration
FAR Part 150	Federal Aviation Regulation on Airport Noise Compatibility Studies
GA	General Aviation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
NPIAS	National Plan of Integrated Airport Systems
PRM	Precision Runway Monitor
RDSIM	Runway Delay Simulation Model
RDU	Raleigh-Durham International Airport
RVR	Runway Visual Range
SM	Statute mile
TCA	Terminal Control Area
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF navigational aid (omnidirectional course information)

Credits:

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